

INTEGRATED URBAN MALARIA CONTROL: A CASE STUDY IN DAR ES SALAAM, TANZANIA

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Abstract. The rapid growth of cities in sub-Saharan Africa, much of it driven by rural-urban migration, is associated with complex transformations of these ecosystems and an intricate set of challenges for malaria control. Urban malaria transmission is substantially less intense and much more focal than in rural and peri-urban settings. However, the danger of epidemics is higher and the presence of substantial non-immune populations places people of all ages at comparable levels of risk. The limited number of breeding sites in urban centers suggests that prevention strategies based on vector control, with emphasis on environmental management, should be a central feature of urban malaria control programs. We focus on malaria in the city of Dar es Salaam, Tanzania. Following a brief review of the 100-year history of malaria control in this urban center, we describe and evaluate a control program that operated from 1988 to 1996 as a consequence of a bilateral agreement between the governments of Tanzania and Japan. We present an innovative urban malaria risk mapping methodology based on high-resolution aerial photography with ground-based validation. This strategy clarifies that remote sensing technology at a level of resolution of one meter is essential if this kind of information is to play a role in guiding the detailed specification of intervention strategies for urban malaria control. The Tanzania-Japan multiple-intervention malaria control program, adaptively implemented over time, is described and evaluated with implications for urban malaria control in sub-Saharan Africa more generally.

INTRODUCTION

Every year, 14 million to 18 million new malaria cases are reported in Tanzania, and 100,000–125,000 deaths occur. Of those deaths, 70,000–80,000 occur in children less than five years of age. The annual incidence rate is between 400 and 500 per 1,000 people, and this number doubles for children less than five years of age. These high rates imply multiple episodes of malaria in a single year for many individuals. The annual mortality rate is 141–650 per 100,000 people, increasing to 300–1,600 per 100,000 for children 0–4 years of age. Malaria is the leading cause of outpatients, deaths of hospitalized people, and admissions of children less than five years of age at medical facilities. As a result, it is considered the major cause for the loss of economic productivity of those between 15 and 55 years old, and an impediment to the learning capacity of people between 5 and 25 years of age. The disease represents one of the most important obstacles to economic development and foreign investment in Tanzania.¹

This scenario is neither novel nor unique in sub-Saharan Africa. Since the early 1900s, malaria was seen as a major threat to development in areas where the disease was endemic.² Diverse and meticulously planned intervention programs were implemented by colonial governments and private entrepreneurs.^{3,4} Multiple techniques combining environmental management, effective housing designs, personal protective measures, and antimalarial drugs were used simultaneously for malaria control.^{5,6} In Tanzania, malaria control efforts started with the Germans in the late 1890s.^{7–10} Despite some financial constraints during certain periods, some form of control program has been maintained ever since.^{7–12}

In Tanzania, as in most countries of sub-Saharan Africa, malaria transmission is very intense, particularly in rural areas. A common situation is low human population density in proximity to a large number of potential mosquito breeding sites. In such areas, it is commonly perceived that the costs of treatment are less than the costs of vector control. In contrast, malaria transmission occurs at significantly lower levels in urban areas, where population density is high, and the num-

ber of breeding sites is reduced.^{13,14} Finally, peri-urban areas are transition zones between high and low transmission. To stress the difference in malaria transmission between rural and urban areas, two recent reviews of studies published after 1980 show that *Plasmodium falciparum* entomologic inoculation rates (EIRs) (defined as the number of infective bites per person per year) in urban settings vary between 0.1 and 33.0, with an average of 7.1 in city centers and 45.8 in peri-urban areas, while the observed range for rural areas was 0.1–884.2, with an average of 167.7.^{13,15}

In urban settings most, if not all, breeding sites can be identified and accessed for vector control. Consequently, prevention strategies based on integrated vector control can now, as in the past, be a central feature of urban malaria control. The use of multiple interventions simultaneously also reduces the pressure on any one tool, e.g., anti-malarial drugs and insecticide-treated bed nets (ITNs), to do the full job of control.

Despite its broad usage, the word urban has an amazingly varied set of definitions, depending upon ecologic and cultural contexts.¹⁶ To facilitate clarity in the present discussion, we require working definitions of urban and, correlatively, urban malaria. We define urban to mean a geographic region whose boundaries are specified by a municipal/national government authority; which contains one or more areas with a high concentration of businesses, housing, paved streets and roads; with a high population density; where agriculture is regulated by a municipal authority; and with a total population size that exceeds 15,000 people. Then, by urban malaria we mean that EIRs are usually less than 5 per person per year in the built-up areas of the specified geographic region, but may be several fold higher in shantytowns, slums, and marginal localities near the periphery of the area; larval breeding sites are highly focal and relatively small in number; *Anopheles* dispersal tends to be no more than a few hundred meters from breeding sites; and prevalence rates vary substantially by location, often by a factor of 2 or more, even within a few kilometers.

Urban malaria control in Africa has a history of more than 100 years.² However, increasing attention is being devoted to this issue as a result of the rapid growth of cities and the fact that by 2025, more than 50% of the people in Africa are expected to be living in urban centers.¹⁷ Successful urban malaria control programs (UMCPs) in the past had the following characteristics: 1) environmental management was a central feature, with several interventions and surveillance methods implemented simultaneously; 2) packages of interventions were adaptively tuned over time to minimize the number of malaria cases per year; 3) 3–5 years were required before a given package of interventions exhibited high level performance; 4) diagnosis and treatment of malaria cases and the use of bed nets and chemical insecticides were a necessary but not a sufficient set of components to ensure a sustainable program; 5) program staff contained people knowledgeable about clinical aspects of malaria, ecology, epidemiology, entomology, and hydrology; and 6) the implementation strategy, including the mixture of tools used, was highly idiosyncratic to the particular locality.^{2–4,6,18}

With the end of the colonial period, the infrastructure and financing of UMCPs has not been uniformly sustained. Furthermore, recent past and contemporary discourse regarding malaria control has primarily focused on rural areas, where the burden is greatest. Nevertheless, rapid growth of urban areas, fueled by high rates of rural-urban migration, together with the recognition of risk of epidemics and the importance of urban malaria control for economic development, has led to renewed interest in this issue.^{19,20}

Because of the breakdown of infrastructure and grossly inadequate financing for urban malaria control in the post-colonial period, many programs have only been effective for short periods of time. Furthermore, we lack documentation and evaluation of a contemporary UMCP that can provide lessons and serve as a template for new initiatives. Filling this gap is particularly salient for current efforts that are emphasizing scaling up malaria control from locally defined special initiatives to national level programs (e.g., the Millennium Development Goals, <http://www.un.org/millennium/> and <http://www.developmentgoals.org/index.html>).

The purposes of this report are two-fold. First we describe and evaluate a UMCP implemented in Dar es Salaam, Tanzania from 1988 through 1996 as part of a bilateral agreement between the governments of Tanzania and Japan. Second, we extract lessons from this experience that are relevant for UMCPs in sub-Saharan Africa more generally.

HISTORY OF MALARIA CONTROL IN DAR ES SALAAM

The history of malaria control in Dar es Salaam dates back more than 100 years, commencing when the area was still a German possession.^{11,21} In 1891, quinine administration was initiated for non-immune whites, Asians, and Africans, and at the turn of the century the first environmental management intervention was introduced, consisting of direct soil work targeted to the larval stages of malaria vectors.^{8,22,23}

In 1901, it was recognized that the land level and the effects of tides resulted in the formation of water collections, surrounding the city even during part of the dry season. However, physical elimination of those collections was technically

difficult and expensive. Application of oil to open water bodies proved inefficient for reducing the number of mosquitoes, and house screening was not cost-effective. Instead, the use of quinine to treat all infected people, and for individual prophylaxis of non-immune populations, remained as the main intervention adopted by the German colonial government.¹¹ This intervention did not translate into significant decreases in malaria transmission.¹² In fact, an experiment conducted in 1913 showed that cleaning a pond, trimming the banks, and larviciding resulted in larger decreases in the positivity index when compared with the effects of quinine administration alone.¹⁰

In 1913, a German ordinance for mosquito extermination was put in place. It provided legal sanction for the destruction of ponds, vessels, tins, and other sources of standing water. Interventions included oiling of water accumulations, indoor house spraying with pyrethrum, and drain construction. By the time World War I started, it is estimated that these control measures contributed to a reduction in the mosquito population in Dar es Salaam of approximately 90%.²²

During and soon after World War I, Tanzania was taken over by the British government, and malaria control was continued through the Royal Army Medical Corps. Interventions were primarily aimed at drainage work, straightening of streams (to increase water velocity), oiling of puddles, cleaning the banks of drains to facilitate the flow of predatory fish, and surveillance of livestock so that cattle would be kept far from streams and swamps, thereby avoiding the creation of hoof prints that could form additional mosquito breeding sites.

Larvicidal aerial spraying was first used in 1945, and the application of dichlorodiphenyltrichloroethane (DDT) to the walls inside houses started in 1946.¹⁸ After World War II, chloroquine was introduced and rapidly became the drug of choice for malaria treatment. The early success of these innovations in chemical vector control and human treatment had the unfortunate negative consequence of diverting attention away from other interventions that had been part of previous integrated malaria control programs.²⁴

During the 1960s, interventions in Dar es Salaam (and other major cities in Tanzania) were primarily based on 1) environmental management including drainage, filling, and other engineering works; 2) surveillance of major development projects (e.g., mining and agricultural estates), airports, and prisons; and 3) community health education. These packages of interventions contributed to marked reductions in larvae of both *Anopheles* and *Culex* mosquitoes in the 1960s, and malaria transmission in urban areas was considered to be of low magnitude.^{24,25}

In June 1971, the World Health Organization (WHO) East Africa Aedes Research Unit, with the collaboration of the Dar es Salaam City Council, carried out a spatially targeted field experiment to test an integrated vector control approach. The interventions specifically adopted for *Anopheles* control included 1) use of larviciding on standing water in wetlands, rice fields, marshes, and edges of swamps; 2) vegetation clearing along streams and in swamps; 3) opening of drains; and 4) use of oil on wetlands. An evaluation after 13 months showed that the density of mosquitoes was significantly reduced in the areas under intervention. The resting density of female *Anopheles* mosquitoes per room in January

1973 was only 0.03 in the intervention area, but 0.33 in a control area.²⁶

In 1972, adverse economic conditions and a policy of decentralization resulted in the deterioration of the health system, and chemotherapy was the only anti-malaria intervention left in place. As a result, the annual number of *Anopheles* collected in Dar es Salaam, which averaged less than 500 during the period from 1967 to 1971, increased more than 10-fold by the early 1980s.²⁷ In 1983, the Ministry of Health (MOH) of Tanzania promoted a reformulation in malaria control policies, re-emphasizing the combination of interventions, including vector control, chemotherapy, and monitoring of drug resistance.

In 1986, the Government of Japan, through the Japan International Cooperation Agency (JICA) submitted a proposal for external assistance on urban malaria control in Dar es Salaam and Tanga. In 1988, the UMCP was launched in both towns. Details of the control program, its effects on malaria outcomes in Dar es Salaam, and its lessons for future interventions are the main focus of the remainder of this report.

ECOLOGY AND EPIDEMIOLOGY OF MALARIA IN DAR ES SALAAM

Dar es Salaam has a hot and humid tropical climate with two rainy seasons: an intense one observed during the months of March, April, and May, and a mild one occurring in November and December. The average temperature ranges from a maximum of 31.5–32.1°C to a minimum of 18.1–18.6°C, and the average annual rainfall is 1,115 mm. A theoretical model based on climate data (rainfall and temperature) characterizes Dar es Salaam as an area with endemic and perennial malaria, with transmission occurring during the entire year.²⁸ According to the city administrative definition, Dar es Salaam has an area of 1,393 km², although most of that area is not currently urbanized. Based on the work done by Briggs and Mwamfupe²⁹ and by Shand (<http://mshand.geog.gla.ac.uk/DAR/tanzania.htm>), and by digitizing maps publicly available (<http://mshand.geog.gla.ac.uk/DAR/tanzania.htm>), we estimate that the urban area in Dar es Salaam was approximately 93 km² in 1978, 259 km² in 1992, and 418 km² in 1998.

Malaria transmission in the urban area of Dar es Salaam is less intensive than in peri-urban and rural areas. This is illustrated by significantly lower percentages of school children infected with malaria parasites (mainly *P. falciparum*) and living in the urban areas (2–10%) compared with those living in the peri-urban and rural areas (40% and 70%, respectively; JICA, unpublished data). The number of breeding sites for malaria vectors in urban areas is reduced because pools of stagnant water become polluted or disappear through drainage work and urban construction.^{6,30} Moreover, environmental management strategies during malaria control campaigns over almost a century resulted in a well-structured drainage network, although it often lacked adequate maintenance.

Plasmodium falciparum is the predominant malaria parasite, accounting for 90% of all cases. It is primarily transmitted by *Anopheles gambiae* and *An. funestus*. The former prefers small and often temporary collections of clean freshwater bodies, although some subspecies can breed in salty water.

The latter is found in permanent water bodies, especially near inland marshes. Different types of breeding sites are found in urban areas of Dar es Salaam, with distinct conditions conducive to high larval production, each requiring specific interventions for control. Since breeding sites are found only in limited numbers around the city, interventions based on vector control targeted at larval stages are more likely to be efficient and cost-effective, especially when emphasis is placed on environmental management (drainage, filling, and clearing vegetation, among others).^{30–32}

Finally, although malaria transmission in the most urbanized areas of Dar es Salaam is less intense than in peri-urban and rural areas, it is important to emphasize that the role played by urbanization in malaria transmission is two-fold. On the one hand, it reduces the number of places that could potentially become *Anopheles* breeding sites, since standing water tends to be more polluted, and there is a major increase in impervious surfaces resulting from building construction and pavement of roads.³⁰ On the other hand, the initial process of urban expansion is accompanied by an increase in malaria rates at the periphery of the city. This is driven by the establishment of new shantytown zones with open sand pits and burrows and by the dangerous encounter at the urban fringe of a population with low malaria immunity coming into contact with parasite carriers migrating from rural areas.

A CONTEMPORARY UMCP IN DAR ES SALAAM: 1988–1996

The UMCP, established in a bilateral agreement between the governments of Japan and Tanzania, was launched in 1988 and closed in 1996. The areas of intervention were Dar es Salaam and Tanga, the two most important port cities and most populated urban centers in the country. The objectives of the UMCP were two-fold: 1) to reduce urban malaria prevalence to the lowest possible level, and 2) to encourage the community to use personal protection measures and to improve their local environment. The Japanese government provided technical and operational expertise, and donated equipment for malaria control, entomologic evaluation, and parasitologic activities, which amounted to US \$17 million during the eight year program. The MOH of Tanzania, the Dar es Salaam City Council, and the Tanga Municipal Council provided additional US \$ 2.7 million to the budget of the UMCP.

Although the major focus in the early years of the UMCP was on vector control, a reevaluation took place after the WHO presented its Global Malaria Control Strategy in 1992, consisting of 1) early diagnosis and prompt treatment; 2) use of selective and sustainable preventive measures, including vector control; 3) detection and confinement of malaria epidemics; and 4) local capacity development.³³ The UMCP expanded its activities in accordance with these new WHO directions, addressing the first two items. Key objectives of the expanded program were to 1) increase people's perception of malaria; 2) involve the community in routine activities to reduce the risks of malaria transmission (e.g., cleaning and rehabilitation of drains); and 3) implement an integrated urban malaria control program based on different types of interventions, but with particular emphasis on vector control.

Although not included in the financial aid of the UMCP,

the JICA also addressed the fourth item of the new WHO directions. Local capacity was promoted by eight in-country training courses (ICTCs), offered between 1993 and 1996, with an average duration of four weeks. A total of 211 laboratory technicians, nurses, and health officers were trained. Three main topics were covered in the courses: 1) vector control, 2) rapid diagnosis using the acridine orange (AO) method, and 3) improved case management for severe malaria. A lack of available personnel to be trained on vector control shifted the focus of the ICTCs to the last two topics, privileging nurses and laboratory technicians, a professional category that had not received local training for many years. The AO technique for malaria diagnosis provides results of blood tests within 3–10 minutes, which is much faster than the more widely used Giemsa staining, which usually takes at least 45 minutes. Such a rapid and efficient diagnosis method helps in avoiding the common practice of prescribing drugs before accurate test results are available. In the long run, this may decrease the risk of drug resistance development.³⁴

Organizational structure. In conformity with the rules imposed by the Japanese government, the UMCP had a project advisor from Japan and a project manager from Tanzania. Six Japanese advisors rotated through the project during its eight years of operation. Few stayed in Tanzania more than two years, the maximum time an average Japanese employee can stay absent from the country. The main role of the advisor was to provide technical expertise to the project manager, and to train local people. Training pertained to resources/equipment distributed by the JICA, identification of breeding sites, and collection of larvae and adult mosquitoes. The trainees were expected to become trainers themselves, guaranteeing the perpetuation of knowledge. However, the JICA had no legal power to enforce this activity. Analogously, once each installment of the grant-in-aid was disbursed in the form of materials and equipment, the JICA had no legal rights to request a formal report of how those resources were used. This lack of integration with the city council represented a limiting factor in turning the UMCP into a sustainable activity.

A Japanese malariologist had an active role in the planning phase of the UMCP, and also in training local people on vector control. The project manager was a medical officer, and during the eight years of the UMCP an annual average of 58 and 636 people worked on professional and operational activities, respectively, in Dar es Salaam. In Tanga those numbers were 21 and 84, respectively.

Evaluations by the project advisors indicate that local people lacked adequate expertise in planning, implementing, and monitoring control interventions. In the first case, the demand was for knowledge about potential sources for mosquito breeding, and choice of the type and amount of chemicals to be used by type of breeding site. Regarding implementation, there was a need for training on insecticide and larvicide use, mosquito and larvae collection, and laboratory analysis. Finally, persons monitoring the UMCP lacked adequate skills in data collection and management. This presented a severe limitation on the level of detail that is available about the performance of individual components of the program. Fulfillment of all of the above needs clearly demanded a team of experts working in collaboration with local people. However, the policy of the JICA only allowed one expert allocated to the UMCP, in addition to the project ad-

visor and a few people doing volunteer work as laboratory technicians.

Types of interventions. Multiple interventions were used in the vector control component of the program. These included chemical larviciding, indoor residual house spraying (IRHS), space spraying of insecticides at ultra low volume (ULV), ITNs, and environmental management. Additionally, application of expanded polystyrene beads (EPBS) was used to control *Culex* larvae. *Culex* mosquitoes are potential vectors of lymphatic filariasis, but they do not transmit malaria. However, the adoption of this intervention increased the popularity of the UMCP in the community.

The implementation of vector control measures was spatially stratified. Dar es Salaam was divided into urban and peri-urban areas. The former were targeted with specific interventions to eliminate mosquito-breeding sites. The latter were roughly 3-km wide, and were considered as barrier zones that would prevent infected mosquitoes from entering the urban areas. However, barrier zones were ultimately based on knowledge that mosquito dispersal was restricted to several hundred meters. A detailed sketch of the types of interventions adopted in each area is presented in Figure 1.

The IRHS and ITNs were the interventions introduced in peri-urban areas. Initially, IRHS was the sole intervention, repeated every 3–6 months in 42 villages. Due to a lack of insecticides, spraying was suspended in 1993 and 1994. In 1995, this activity was resumed in 21 villages (the number of villages was reduced as a result of the progressive urban expansion), with a population of approximately 90,400 people. Coverage of 94% of the houses was achieved. However, spraying became unpopular in the community, and was gradually replaced by ITNs. In 1992, ITNs were introduced on an experimental scale in two villages, as highlighted in Figure 1. In 1994, ITNs became fully operational. Retrospectively, it was noted that the price of ITNs set by the Dar es Salaam City Council was too high for most of the people living in the peri-urban areas targeted by the UMCP, and a large proportion was sold to any person in the city that could afford them.

The use of chemical larviciding, ULV, EPBS, and environmental management were the main interventions in the urban areas. Insect growth regulator (IGR) replaced larviciding in 1994, since its effect lasted for a longer period, allowing applications to be carried out on a monthly basis, instead of the weekly use of larvicides. Regarding environmental management, the control measures included the filling of a pond, cleaning of drains (a total length of 75.7 km between 1990 and 1993), and new drain construction.

Drain cleaning was considered as one of the most effective measures implemented by the UMCP. For example, the Kibasila drain, located in the Temeke area, had no rehabilitation for many years, which contributed to the creation of standing water bodies where *Anopheles* larvae were found. Cleaning of the drain resulted in a reduction of 0.6 meters in the water level of a nearby swamp. While Kwa Azizi Ali drain was partially rehabilitated, Bungoni drain, in Ilala, was totally rehabilitated. The latter was constructed in the colonial era, improved and rehabilitated in the early 1970s, but abandoned in the mid 1980s. As a result, the water flow was blocked by silt, vegetation, and waste, increasing the ground water table, favoring the occurrence of flooding during the rainy season, and offering ideal breeding conditions for mosquitoes.

The Bungoni drain had many of its sections submerged by

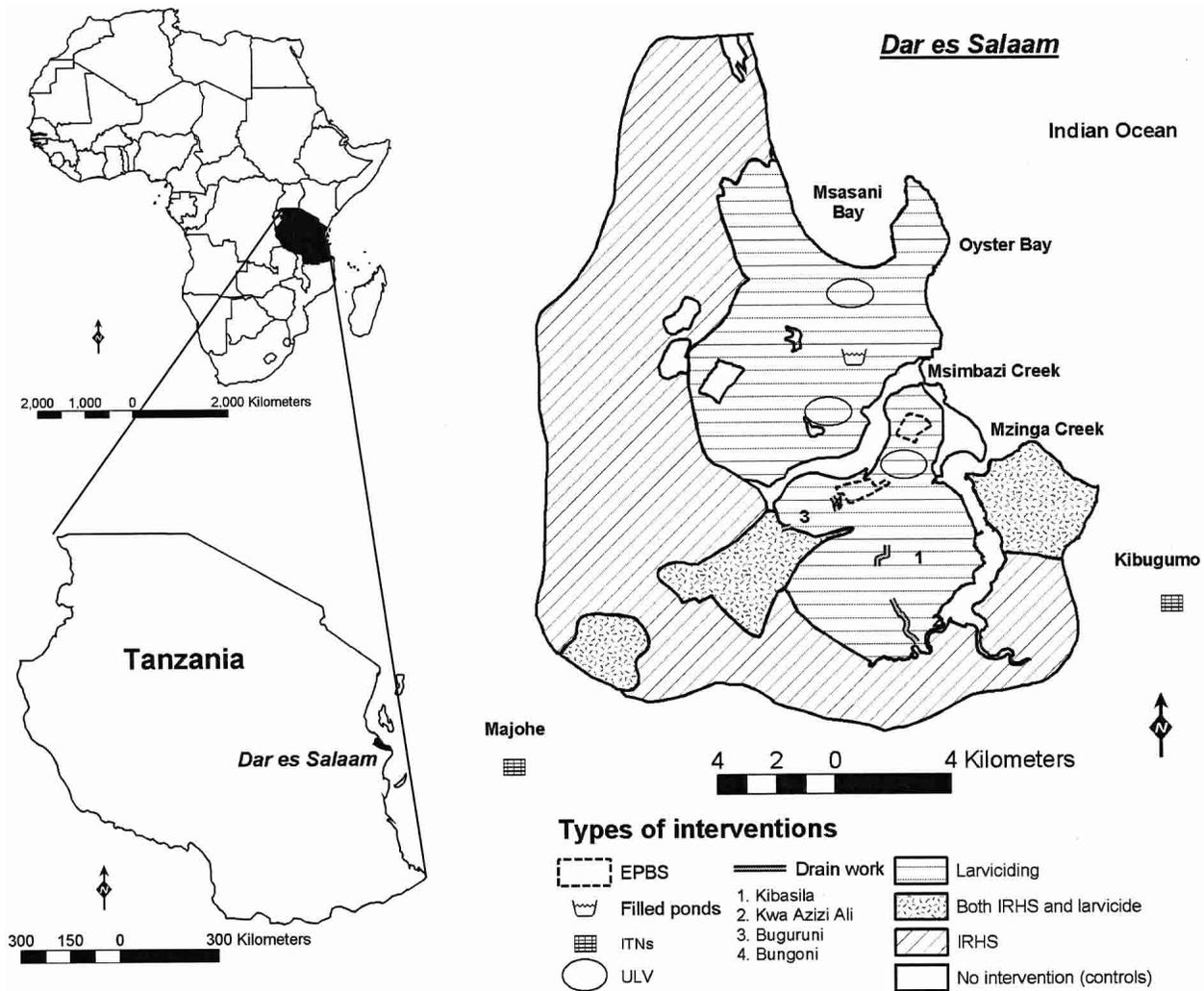


FIGURE 1. Urban malaria control program plan for vector control interventions in Dar es Salaam, Tanzania. EPBS = expanded polystyrene beads; ULV = ultra low volume; IRHS = indoor residual house spraying; ITNs = insecticide-treated bed nets.

9–15 cm. Rehabilitation work started in 1996, and involved active community participation (both physically and financially). It was a major operation that mobilized people from the JICA and the local government, a team of journalists, and more than 100 people from the community. As a result, significant reductions in the density of both *An. gambiae* and *An. funestus* were observed, and the flooding problem was dramatically reduced. The outcome was so positive that the community started a mobilization to gather funds for maintenance of the drain. Furthermore, due to media coverage, other communities indicated a willingness to engage in similar kind of drainage work.

Finally, a new drain was constructed in collaboration between the UMCP and a non-governmental organization (Plan International). The drain is located in the Buguruni area, and has a total length of 800 meters.

Risk assessment. The UMCP introduced systematic registration of *Anopheles* breeding sites with a combination of geographic reconnaissance, high-resolution aerial photography, and ground-based validation. For the purpose of geographic reconnaissance, three main sources were used, among the six geographic publications available: 1) a topographic

map on a 1:50,000 scale; 2) urban maps on a 1:2,500 scale (the best resolution available at the time the UCMP was in operation); and 3) a set of aerial photographs on a 1:5,000 scale, produced by enlarging, by a factor of 2.5, black and white aerial photographs taken in July 1992.

The aerial photographs were analyzed with the aid of a stereoscope, rendering a three-dimensional image that facilitated the detection of depressions in the terrain. A photo interpretation procedure was developed and potential mosquito breeding sites were identified. An in-depth ground-based validation of those sites was undertaken and a database of breeding sites was created. Additionally, new house construction sites were identified during the ground survey, and open pits were systematically dipped for mosquito larvae. The database of breeding sites included information on the name of the region where the site was located, its type, the recommended strategy for its elimination, Universal Transverse Mercator (UTM) coordinates, seasonality, and rank, which is a qualitative measure roughly indicating the carrying capacity for larvae and pupae development. We present rather more detail about breeding sites around the city to clarify the diversity of ecologic conditions associated with urban malaria

and the level of technical understanding necessary for its control.

A total of 43 locations with multiple *Anopheles* breeding sites were identified. This small number highlights the fact that sources of malaria vector breeding in urban areas are much fewer if compared with rural areas. An urban malaria risk map is shown in Figure 2. A large number of breeding sites tend to be concentrated in lower elevation parts of the city, or near drains that require cleaning or rehabilitation. Their carrying capacity for larvae and pupae development varies, as does the volume of water that they can store. These differences depend partly on the type of breeding site. *Matuta* (ridges for planting crops such as sweet potato, rice, and beans, among others, often made on grounds with high water table) and sand pits are by far the most important types of breeding sites. Their occurrence is more frequent in creeks, swamps, and salt works. Ground water penetrates at those sites by filtering through the soil, which is relatively free of pollution and natural larvae predators, such as backswimmers.

For ease of visualization and better description, all 43 locations with *Anopheles* breeding sites shown in Figure 2 were divided into four groups indicated by the letters (a), (b), (c), and (d). For each of those groups, the breeding sites are detailed by type in Figure 3.

Group (a) includes the Msasani Bay area, Regent Estate, Kinondoni, and Mwananyamala, and is shown in detail in Figure 3a. The pipe leakage located on Kimweri Avenue at Msasani Bay was small enough to be avoided by vehicles, therefore offering ideal conditions for *Anopheles* breeding. All the sites classified as sand pits, swamps, and paddy offered medium carrying capacity for larvae and pupae development, while those identified as *matuta*, seepage, and salt pans (Msasani salt works) had very high carrying capacity. Two puddles were found in this area, but only that located in the

northern part had larvae present and offered a very high potential for larvae and pupae development (its water capacity was 600 m³).

Group (b) comprises the breeding sites registered in Magomeni, Upanga, Kariakoo, and Kigogo. Most of them were concentrated south of the Mzimbazi Creek area, along riverbanks and drains, in a location free of buildings, as shown in Figure 3b. Sand pits and salt pans offered medium-to-low risk for breeding capacity, while swamps and *matuta* had a higher risk. The only paddy in the area had a high potential for larvae and pupae development, and an estimated total water volume of 5,000 m³.

Group (c) consists of breeding sites found in Keko, Mguhani, Chang'ombe, Temeke, and Mguhani. Three drains that were cleaned or rehabilitated by the UMCP, as highlighted in Figure 1, were also located in this area, and many breeding sites with high potential for larvae and pupae development were found in their surroundings. Four breeding sites were registered near Kwa Azizi Ali drain, as detailed in Figure 3c: two swamps, one seepage, and one marsh. The latter had a total water volume of 4,000 m³ and offered maximum carrying capacity for larvae and pupae development. Another high-potential marsh was found near Kibasila drain, with a total of 6,400 m³ of water. *Matuta* sites in Tazara Quarters, near Kurasini drain, offered high risk for mosquito breeding: ridges measuring approximately 1.5 × 20 × 0.6 meters (width × length × depth), with 0.3 meter-wide ditches between them, had a water volume capacity of 2,000 m³.

Finally, group (d) encompasses the breeding sites registered in Vingunguti. Two clusters of breeding sites are observed. The first one, on the upper right corner of Figure 3d, is in the urban fringe, the division between urban and peri-urban areas defined by the UMCP. With the exception of the wells, all other sites offered high breeding capacity, and accumulated a large volume of water (2,000 m³ in the paddy and 3,000 m³ in the pond, which was in the area where the Buguruni drain was constructed). The second cluster, on the bottom left corner of Figure 3d, is in the peri-urban area, and was subjected to both larviciding and IRHS. All breeding sites had a medium risk for mosquito breeding, with the exception of the paddy, which had a low potential.

Of those 43 mosquito breeding locations, two deserve special attention. The first characterizes *matuta* in Tazara Quarters, a residence complex measuring approximately 140,000 m², with 20% of this area occupied by buildings, as illustrated in Figure 4. It was one of the most productive breeding places for *An. gambiae* in the urban center of Dar es Salaam.

The area has a high water table, favoring agricultural practices. The water that stands in the ditches between the ridges is usually clean and favors *Anopheles* breeding. Trenches with standing water were found for the most part in the northeast corner, mainly used for sweet potato and rice cultivation, covering an area of about 10,000 m². A thorough analysis of one randomly selected area measuring 45 m² revealed an *Anopheles* density of 13.8/m². If the same density occurred throughout Tazara Quarters, almost two million *Anopheles* could be expected to breed in this area. This extrapolation exhibits the extreme high risk of the area.

In 1993, nearly 100 trenches between ridges were observed and treated with IGR. The main drain in the area, Tazara drain, was for the most part blocked by silt, debris, and veg-

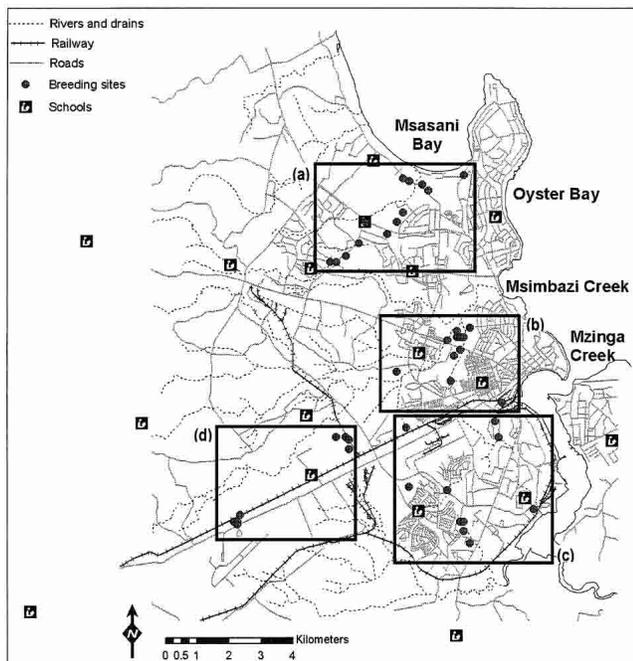


FIGURE 2. Urban malaria risk map for Dar es Salaam, Tanzania, 1993.

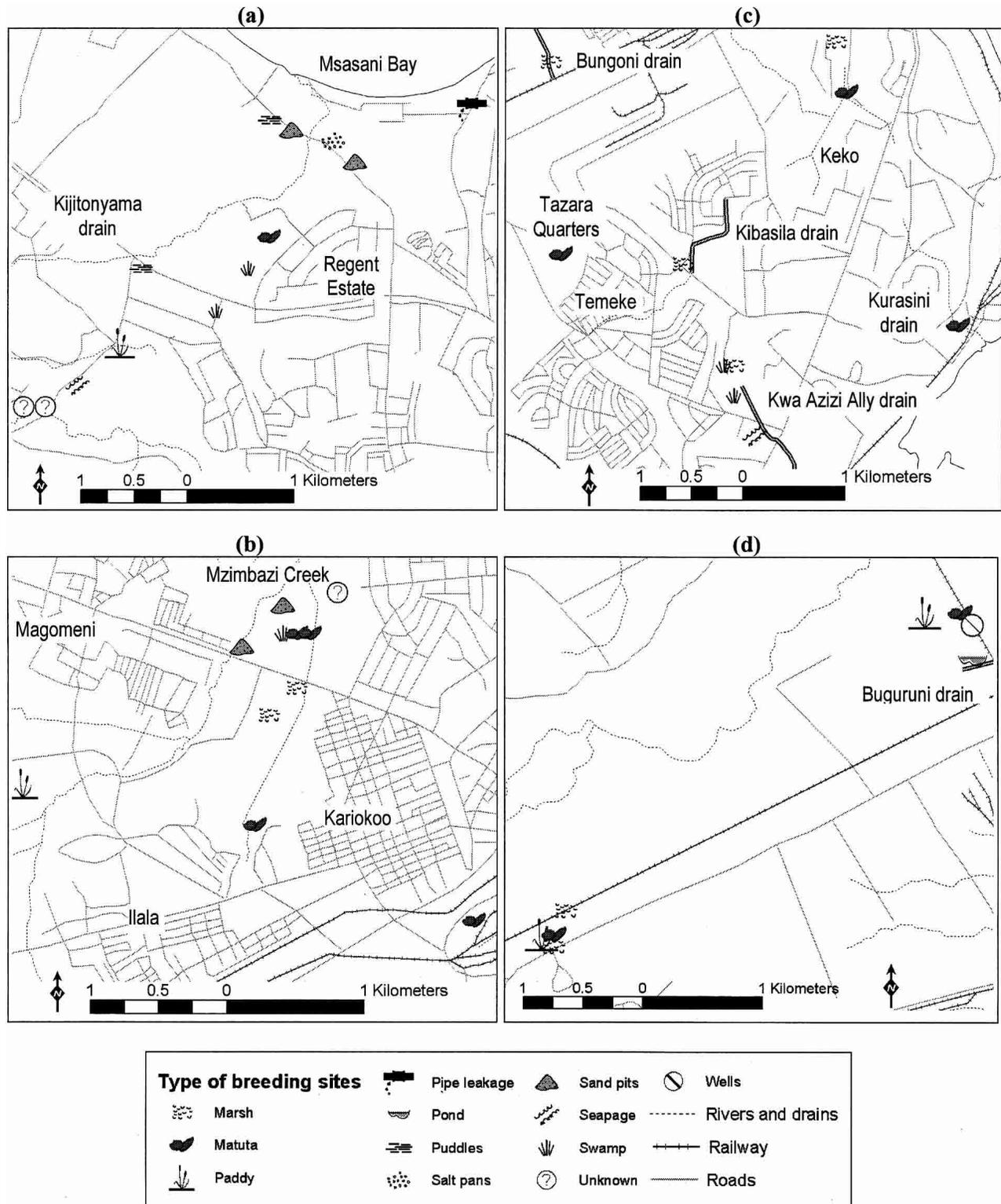


FIGURE 3. Locations and type of breeding sites registered in Dar es Salaam, Tanzania, 1993.

etation, which prevented the natural flow of water. Consequently, a meticulous plan for drain clearing was undertaken.

The second area details the Msasani salt pans, which are located along Bagamoyo Road. They receive storm water from upper lands through a network of drains in the sur-

roundings. The water should naturally pass through the area and end up in the Indian Ocean. However, three main issues contributed to the impediment of the watercourse. First, the salt works were abandoned and the standing salt pans blocked the passage of water. Second, housing development in the



FIGURE 4. Sweet potato cultivation identified by aerial photo interpretation in Tazara Quarters, Temeke, Dar es Salaam, Tanzania.

neighborhood also resulted in blocking of the natural course of water. Third, most of the existing drains had no maintenance for many years. As a result, the area was considered as one of the most productive sources of mosquito breeding in urban Dar es Salaam, often subjected to flooding.

The information provided by the aerial photographs allowed the elaboration of a detailed sketch of the area, as shown in Figure 5. This facilitated the survey of potential breeding sites and the planning of interventions for vector control. A total of 70 salt pans were sketched. On average, 38% of the pans were covered with water, with an average depth of 5 cm, a water volume of 11 m³, and an average area of 493 m², varying between 94 m² and 1,375 m². Of the 70 pans, 45 underwent detailed surveys for *Anopheles* and *Culex* eggs, larvae and pupae. Ground surveys also collected information on the type of vegetation and algae present in the pans, salinity of water, and presence of natural predators (backswimmers and fish). Overall, 71% and 44% of the pans had no backswimmers or predator fish, respectively.

A detailed intervention plan was implemented based on the above information. It primarily relied on drainage work, whose need was verified during the ground survey. Drainage work was undertaken by the UMCP between June 1994 and May 1995. It consisted of the rehabilitation of a main drain with an approximate length of 2 km, a width of 21 meters, and a depth of 0.75 meters. Additionally, existing ridges between the salt pans were broken to connect lower and upper pans. Although this simple drainage work could not eliminate all the breeding sites, the few remaining were successfully treated with IGR. As a result, there was a significant decrease in the water table, and flooding was not an issue anymore. Only four of the salt pans surveyed in 1995 still supported larvae development, and many had dried out. Reassuringly, *Plasmodium* parasite rates in the nearby schools were reduced after the drainage work, in parallel with sharp reductions of adult mosquito densities.

The use of stereoscopic images was a key component for

the adequate risk assessment of potential *Anopheles* breeding areas. Prior to their use, bodies of water were being treated by the local team with no appraisal of their potential for larvae development. Although the photos cannot replace ground-based work, they do facilitate the planning and implementation of interventions.

It is worth mentioning that satellite images could be an alternative source of information for the identification of potential breeding sites, if they have the proper level of spatial resolution. This resolution must be smaller than the average size of the water bodies to be identified, otherwise they will not be distinguishable in the image interpretation.³⁵ Consequently, Landsat images (<http://landsat7.usgs.gov/index.php>) with 30 meters of spatial resolution would not be the most appropriate source for the study of urban malaria transmission (Landsat TM and ETM+ have been largely used for disease modeling and risk mapping purposes in many settings other than urban areas).^{36,37} For that matter, Spot images (<http://www.spot.com/>) with 20 meters or 10 meters of spatial resolution would be of limited use, since important breeding sites with overall size smaller than 10 meters would not be visible. Therefore, resolution of one meter or less is essential for urban malaria risk mapping, although financial and technical constraints can play a crucial role in their use. The cost per km² of high-resolution satellite images can vary from US\$ 19.80 to US\$ 30.00, which is extremely expensive data given the limited budget available for the health sector in countries where malaria is pervasive. In addition, the higher the spatial resolution, the higher will be the number of days needed to cover the whole earth (temporal resolution). As a result, fewer images will be available during the year, which can be a problem in tropical areas, where cloud cover is an important issue for image selection. However, once financial resources are available, images can be ordered for chosen times of the year and for a specific location. High-resolution satellite images include Kometa (<http://www.sovinformsputnik.com/>), with two meters of spatial resolution, Ikonos (



FIGURE 5. Msasani salt pans in Tanzania identified by aerial photo interpretation, planned drainage work, and abundance of *Anopheles* larvae between June 1994 and May 1995. Areas marked with **orange** in the aerial photograph indicate potential sites for *Anopheles* breeding, which were investigated in the ground survey.

www.spaceimaging.com), with one meter of resolution, and Quickbird (<http://www.digitalglobe.com>), with the best spatial resolution commercially available to date, namely 0.61 meters.

Financial resources. The total amount of the grant aid provided by the Japanese government for the UMCP was approximately US\$ 17 million, disbursed in five phases. In accordance with the policy of the JICA, there was no transfer of resources in cash or for payment of local manpower. Instead, the budget was distributed in the form of material and equipment for six main activities, as detailed in Table 1.

The Tanzanian government also provided financial resources for the UMCP, mostly for the payment of personnel. A total of US\$ 2.7 million was allocated by the MOH (13.4%), the Dar es Salaam City Council (65.2%), and the Tanga Municipal Council (21.4%).

Some specific malaria control interventions can be analyzed in terms of unit costs. The ITNs were donated by the Japanese government (at an approximate cost of US\$ 2.73 each), but sold by the Tanzanian government, to create a revolving fund to be used uniquely for ITN purchasing. The unit cost of IRHS was US\$ 6.00 per house in Dar es Salaam, and it is important to note that the target dose was doubled in 1992 due to reduced susceptibility of mosquitoes to Fenitrothion. Regarding EPBS, the cost of this intervention was US\$ 0.006 per pit treated in Dar es Salaam, with a consumption of 0.9 kg of beads per pit. The ULV application had a cost of US\$ 1,588 per km covered by the spraying truck in Dar es Salaam.

Significant differences were observed in the unit costs of interventions in Dar es Salaam and Tanga. For example, IRHS and EPBS cost twice as much in Tanga in comparison with Dar es Salaam. This can be partially explained by the fact that Tanga had a strict leader, who may have decided to apply higher dosages of insecticides and beads to achieve better and faster results.

Finally, although ICTC was not included in the UMCP budget, it is worth mentioning that the training courses offered between 1993 and 1996 had a cost of approximately US\$ 335 thousand.

ENTOMOLOGIC AND PARASITOLOGIC IMPACTS

The entomologic and parasitologic consequences of the intervention packages in the UMCP were assessed at regular

intervals during each year. Larval and adult mosquito densities were used to appraise entomologic impacts. The former was assessed through regular searches of breeding sites. Adult mosquito densities were measured by two methods: 1) mosquito catch after spraying rooms in the morning (while the mosquitoes were still resting on the walls) and 2) light trapping, following standard procedures established by the Centers for Disease Control and Prevention. Significant variations in adult mosquito catches were observed, and factors such as location and type of the house, season of the year, and regular use of insecticides by the household played a major role. Mosquito catches were much higher in houses located less than 50 meters from the nearest breeding site, when compared with those located ≥ 200 meters from the sites. Mosquito catching peaks occurred mainly after the short or the long rainy season, depending on the location and type of the breeding site.

Malaria prevalence was assessed among randomly selected school children 6–16 years old at schools located in Dar es Salaam, as shown in Figure 6.

Approximately 300 children were examined in most schools, with a maximum of 778 children examined in Kigamboni school in March 1989. All positive cases were treated with chloroquine. At the inception of the UMCP, six schools were selected for monitoring purposes: two in the area under IRHS, two in the city center where larviciding was used, one in an area where both interventions were implemented concurrently, and one located outside the urban and peri-urban areas of Dar es Salaam, as shown in Figure 6. In 1993, the number of schools was doubled, but the frequency of data collection had to be reduced due to operational and financial reasons. Prior to 1991, data collection occurred almost on a monthly basis.

The annual parasite rates observed in the six schools during the whole period of operation of the UMCP had four important features. First, there was a significant impact on the parasite rates immediately after the program was launched. The graphs in Figure 6 show sharp decreases in the rates from 1988 to 1989, regardless of the type of intervention. Part of the decrease can be attributed to the fact that children in schools were treated with chloroquine if their blood tested positive for *Plasmodium*. However, the maintenance of the lower levels of parasite rates is most likely a consequence of the vector control interventions.

TABLE 1
UMCP budget allocation by program component*

Component	Items	% of Budget
Malaria control operation	Insecticides, Hudson pumps, backpack spraying units, polystyrene beads, vehicles (all-wheel drive cars, trucks, minibuses, and motorcycles), ITNs, office equipment (printers, photocopy machine, generators, mimeograph, etc.), garment for spraymen	67
Health education	Production of an educational movie on malaria control, VCR, video cameras, video duplicator and edition set, material for poster printing and drawing, vehicles, overhead projectors, generators, cameras, speakers, copying machine	13
Equipment for drainage work	Hydraulic excavator, wheel loader, swamp dozer shovel, carrier, seep's foot roller, motorcycles	10
Parasitologic and epidemiologic evaluation	Printers, computers, software, floppy disks, microscopes, microscopes slides, calculators, uninterruptible power supply, staining jars, petri dishes, reagents	4
Entomologic evaluation	Mosquito traps, dippers and pans for larval collection, batteries, thermometers, cameras, insect needles and pins, test tubes, white cloth sheets, mechanical aspirator	3
Laboratory strengthening of the Malaria Service Unit	Microscopes, centrifuges, copying machine, pH meter	3

* UMCP = urban malaria control program; ITNs = insecticide-treated bed nets.

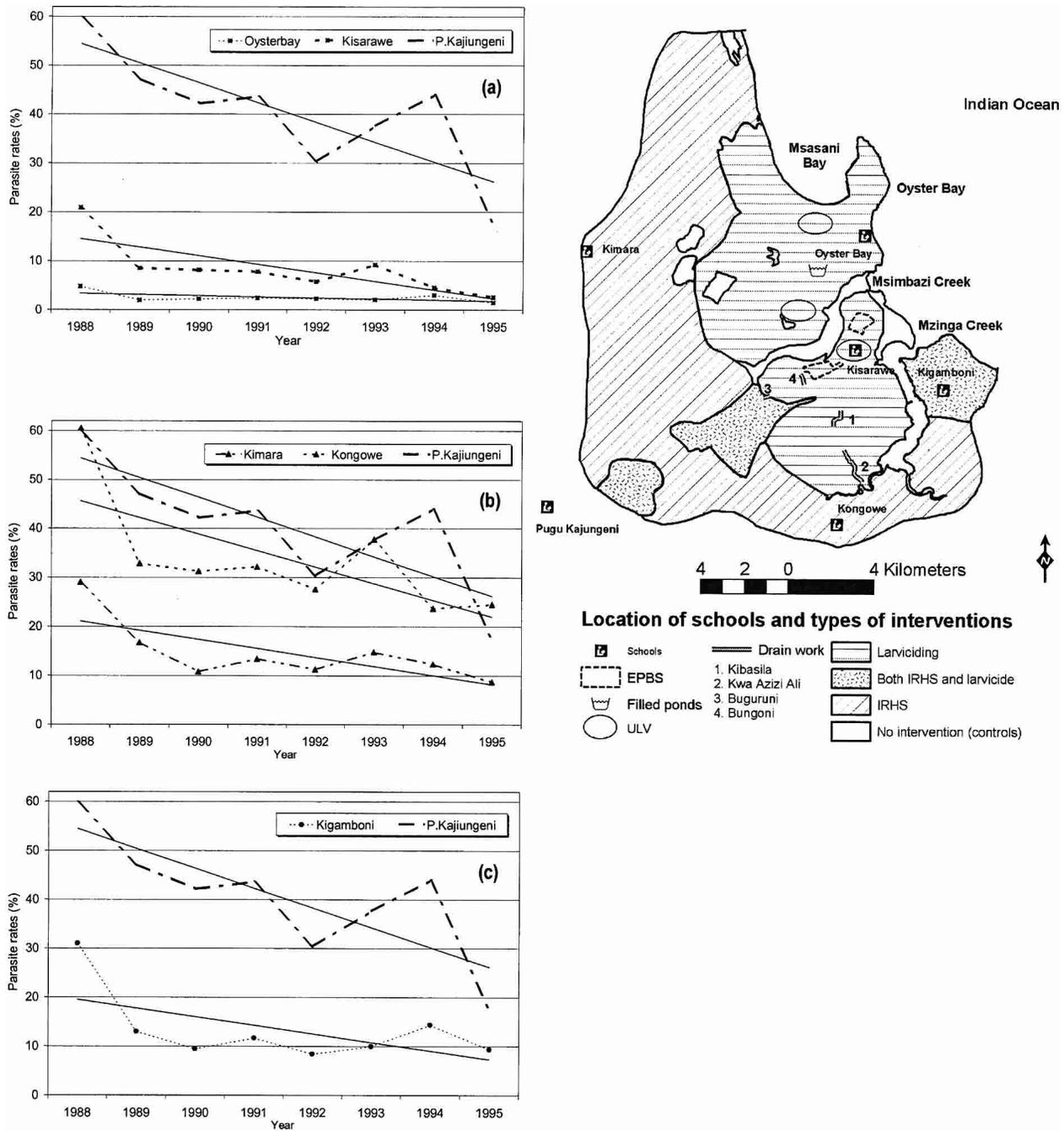


FIGURE 6. *Plasmodium* parasite rates observed among school children and location of schools, by type of intervention in Dar es Salaam, Tanzania, 1988–1995 (a), Schools located in a larviciding treated area; (b), Schools located in an indoor residual house spraying (IRHS) treated area; (c), Schools located in areas treated with both larviciding and IRHS. The Pugu Kajiungeni school is included in all graphs for comparison since it was located in an area outside the limits of the urban malaria control program. EPBS = expanded polystyrene beads; ULV = ultra low volume.

Second, except for Oyster Bay and Kigamboni schools, all changes in parasite rates observed during 1988 and 1995 revealed statistically significant decreases. Oyster Bay is located in a well-developed area of Dar es Salaam, and in 1988 registered the smallest parasite rate among all schools, 4.8%, which decreased to 1.5% in 1995. In this particular case, variations in the rate will be so subtle that the benefit of vector control interventions is difficult to identify. However, the observed decreases in other highly built up areas can be attrib-

uted solely to the interventions. As shown in Figure 7, the Oyster Bay and Kigamboni schools are located in areas where urbanization took place before the 1970s. Therefore, it is likely that the positive effects of urbanization in reducing malaria transmission were already in place before the onset of the UMCP. On the other hand, in the peri-urban areas part of the decrease could be a result of the intensification of urbanization.

Third, the graphs in Figure 6 also show that parasite rates

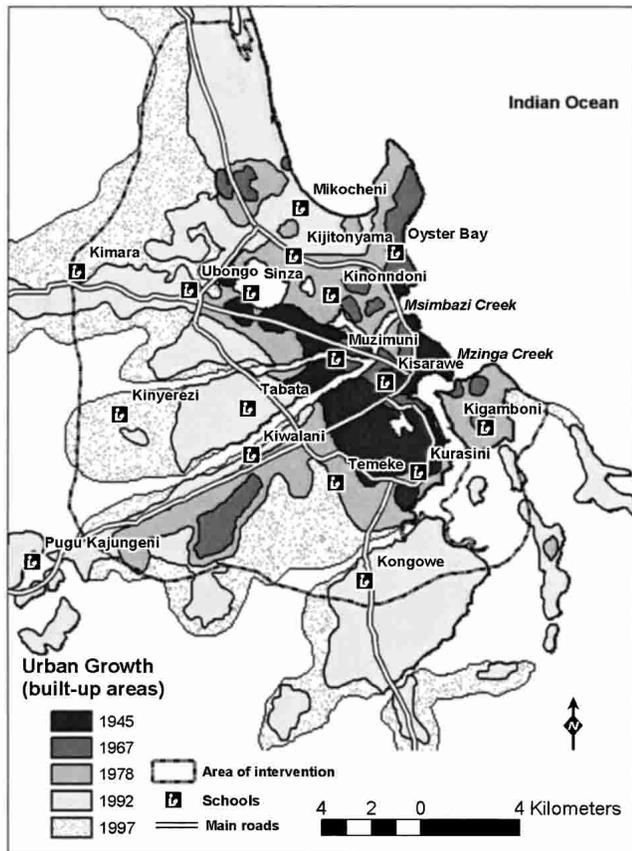


FIGURE 7. Urban growth in Dar es Salaam, Tanzania (1945–1997), area of the urban malaria control program UMCP intervention for malaria control, and location of surveyed schools.

among schools located in the urban, peri-urban, and rural areas had different magnitudes. While they were small in built-up urban areas, progressive increases were observed in peri-urban and rural regions. Additionally, rates were higher in the southern part, which is less developed when compared with the areas further north. This may reflect the impact that the Mzinga Creek had over time in the development of the city, resulting in marked differentials of urbanization in the northern and southern portions of Dar es Salaam.²⁹ Despite the observed decline in parasite rates, this geographic pattern remained the same at the end of the program. It corroborates the distinctive general characteristics of urban and rural malaria in African countries mentioned earlier.^{13,14,38}

Finally, the decrease in parasite rates was significant in areas where no control interventions were in place, but where urban expansion occurred. Pugu Kajungeni school, which is located outside the UMCP limits, showed a decrease in the parasite rate from 59.9% in 1988 to 17.4% in 1995, which is smaller than the initial level of Kisarawe School in 1988 (20.9%), which is located in the southern part of the urban center. The dynamic process of urban frontier expansion, illustrated in Figure 7, gradually reached that school, and before the UMCP was phased out, the area was already considered as urbanized.²⁹ Kongowe and Kimara schools were also affected by the urban growth of Dar es Salaam, and part of the observed decrease in their parasite rates might be a consequence of this process. Therefore, in assessing the conse-

quences of any UMCP, the dual effect of urbanization itself must be regarded as an intervention.

WHAT DID THE UMCP ACCOMPLISH?

A major contribution of the UMCP was the stereoscopic aerial photo interpretation routine that allowed the rapid identification of potential breeding sites and the elaboration of malaria risk maps. An important feature of the analysis was the determination that images with resolution down to one meter are essential if a remote sensing technology is to play a role in guiding the implementation of a control program. While vector control is a central feature of urban malaria control, given the reduced number of breeding sites and the large size of contemporary municipal areas, it will only be effective when those sites can be detected and targeted. The knowledge acquired through the combination of cartographic data and aerial photo interpretation represents a unique tool that can be used for urban malaria control in many other African cities. This technology becomes increasingly important as cities constantly expand in size with accompanying rapid ecosystem transformation. Moreover, the limited budget of most African countries can be an obstacle to the use of satellite images, but aerial photographs are periodically produced in most cities for census or urban planning purposes.

A qualitative assessment of costs, effectiveness, technical feasibility, and sustainability of the different vector control measures used in the UMCP was provided by the program director and is presented in Table 2. Sustainability was determined by three main issues: 1) ease of operation; 2) low purchasing cost; and 3) degree of community involvement demanded. Therefore, although re-impregnation of ITNs requires low material and operational costs, it depends on the active participation of the community to become sustainable.

Qualitatively, it is clear that environmental management, particularly via the maintenance of drains, is especially important for a sustainable malaria control program. Quantitative support for the cost-effectiveness of environmental management techniques, of which drainage was an important component, was demonstrated for an UMCP at Kitwe in the copperbelt region of Zambia in 1935–1950.⁶ A comparable analysis for the UMCP described in this report and for other urban programs that will be implemented under Global Fund initiatives is a high priority for the future design and implementation of urban control programs (<http://www.globalfundatm.org/fundingproposals/approvedproposalsround2.html>).

In addition to these points, it is important to underscore the fact that malaria prevalence rates among school age children were reduced by approximately 50% over the eight-year period that the UMCP was operative (1988–1996). These reductions occurred over very diverse ecologic conditions around the city and at the periphery. Undoubtedly, with a more focused and sustained program that builds on the knowledge base acquired during the UMCP, still more impressive reductions in transmission could be realized. Doing this where local, regional, and national governments, not only in Tanzania, but elsewhere in sub-Saharan Africa, play a dominant and sustaining role represents the challenge and opportunity created by the substantial new funds that have recently been committed for malaria control in the region (<http://www.globalfundatm.org/>).

TABLE 2

Qualitative assessment of costs, effectiveness, technical feasibility, and sustainability of vector control measures adopted by the UMCP, and prioritization of interventions, as assessed by the program manager*

Vector control interventions	Cost†		Community effectiveness‡	Technical feasibility‡	Sustainability‡	Priority§
	Material	Operational				
IRHS	+++	+++	+	+	-	C
ITNs distribution	+++	++	+	++	-	C
ITNs re-impregnation	+	+	+/-	++	+/-	B
Larviciding	++	++	+	+	-	C
IGR	++	+	++	++	++	A
ULV	+++	++	-	+	-	C
EPSB	++	++	-	+++	+	B
Drain maintenance	+	++	+++	+++	+++	A

* IRHS = indoor residual house spraying; ITNs = insecticide-treated bed nets; IGR = insect growth regulator; ULV = ultra low volume; EPSB = expanded polystyrene beads.

† + = least expensive measure for control; ++ = medium costly intervention; +++ = most expensive intervention.

‡ - = no effect; +/- uncertain effect; + = positive effect; ++ = strong positive effect; +++ = very strong positive effect.

§ The scale for the qualitative assessment of the prioritization of interventions ranges according to the combination of cost, community effectiveness, feasibility, and sustainability. A = intervention with the highest priority; B = intervention with a medium priority; C = intervention with the least priority.

An important lesson of the program is that community participation turned out to be much more difficult to achieve than was anticipated *a priori*. Although the health education provided to communities made people more aware of the problems of malaria, political commitment and rigorous publicity campaigns are needed to promote activities such as community-based drainage rehabilitation and maintenance. A clear example of the potential of these activities was the successful drainage work at the Bungoni drain described earlier. The enforcements promoted by the German ordinance were appropriate for a colonial setting, but are not likely to succeed in present independent Tanzania. Therefore, the government has a crucial role in promoting awareness of the problems, and pointing to alternatives for preventing and solving them. Through this mechanism, community cooperation and involvement may be achieved successfully.

Finally, the positive results of the project stimulated communication with other donor agencies, including the WHO, United Nations Children's Fund, and the World Bank. This was a major achievement, since until the early 1990s JICA was the only major external donor providing assistance for malaria control in Dar es Salaam.

CONCLUSIONS

During its eight years of operation, the UMCP provided many lessons that should be considered for future malaria control initiatives in Dar es Salaam, in particular, and in other urban African settings more generally. The project clarified that 1) malaria control in urban settings can be achieved by a combination of multiple interventions, namely vector control and rapid diagnosis and treatment; 2) community health education and active participation is a crucial step for reduction in malaria incidence, prevalence, and successful surveillance; and 3) the use of remote sensing data with high spatial resolution facilitates the identification of potential *Anopheles* breeding sites in the ecologically heterogeneous and dynamic urban environments and plays a key role in targeting control strategies.

For nearly a century, drainage work in urban Dar es Salaam has been a key feature of malaria control. Past efforts illustrate that the construction and maintenance of drains is one of the most important measures for reducing mosquito density. They facilitate flood control and reduce the size of

marshy areas and general water accumulation. Since Dar es Salaam already has a well-established drainage network, financial resources could be spent in the future on clearing and maintenance, which are far less expensive than constructing new drains. Experiences similar to the work at the Bungoni drain would reduce expenses even further.

This intervention could also play an important role in malaria control in other urban areas in Africa. The magnitude of initial investments would depend on three issues: 1) the number of drains already constructed; 2) the characteristics of the soil, topography, and level of water table; and 3) the extent of community involvement that can be achieved. Nevertheless, it is important to keep in mind that although the initial cost of this intervention might be high, it will be amortized over time, since only maintenance of the drains would be necessary in the future, a duty that can be taken over by the community.^{39,40}

The current pace of urbanization and population growth in Africa suggests that a large proportion of people will be exposed to malaria transmission in urban zones.¹⁷ In fact, we estimate that at the present time, 198 million Africans live in urban areas at risk of contracting malaria, and that 24.8–103.2 million clinical attacks occur annually in those areas.²⁰ In Dar es Salaam, the built-up areas increased at an annual rate of 2.2% between 1945 and 1967, but between 1992 and 1997 the annual growth rate increased to 10.1% (these numbers were based on the information available at <http://mshand.geog.gla.ac.uk/DAR/tanzania.htm>). The scenario for many other major urban centers in Africa is similar to Dar es Salaam. Consequently, the adoption of integrated malaria control with special emphasis on environmental management would be a decisive factor to guarantee that malaria in urban areas does not grow at the same pace as urbanization and population. The UMCP described in this report and the series of interventions implemented in Dar es Salaam in the past prove that urban malaria control is feasible and can be effective.

An important limitation of the JICA program was the lack of a comprehensive monitoring and surveillance system for all aspects of the program. In the context of breeding site surveillance, there should be maps that are updated in real time, e.g., weekly or monthly, depending on the larval assessment schedule. The EIRs should have been assessed around the city, emphasizing locations proximal to documented and/or

potential breeding sites and also proximal to schools where parasitologic assessments were in progress. This would have facilitated a direct assessment of the impact of larval control and management of drains on the EIR. It would also have facilitated the documentation of associations between the combination of larval control, environmental management, and case management of school age children and malaria incidence and prevalence rates. The impression from the extant JICA data is that drug administration to diagnosed children was the essential intervention that initially lowered the malaria rates. However, larval control and environmental management were central to the longer term maintenance of low levels of malaria rates. It would be important for future programs to quantitatively document these relationships. Doing so in current control initiatives in Dar es Salaam could then serve as a prototype for monitoring and surveillance of urban malaria control programs on a broad scale in sub-Saharan Africa.

Data collection on school-age children in the JICA program provides no basis for inferring the demographic composition of neighborhoods in the city, including those which are proximal to the schools. Such information is essential if we are to have defensible assessments of the impact of control measures on malaria rates in the diverse ecosystems across Dar es Salaam. To achieve this critical population-level aspect of monitoring and evaluation, we require a demographic surveillance system (DSS) incorporating multiple cycles of household-level surveying each year that includes malaria-specific modules.^{41–46} An urban DSS for Dar es Salaam, analogous to the rural Tanzania DSS systems, will be an integral part of a new control initiative currently getting under way under the auspices of the Dar es Salaam City Council.

A missing element from the JICA program that would be of prime importance for planning and implementing UMCPs in the future is a rigorous cost-effectiveness analysis. One cannot fault the JICA program on this point because there are methodologic issues that remain to be resolved and that more properly belong in a research project. For example, we currently lack defensible algorithms for attributing the impact of program-specific interventions on outcomes distinct from the impact of the process of urbanization itself. The rapid expansion of the geographic area defining the city of Dar es Salaam, the introduction of substantial areas with impervious surfaces that are inhospitable to *Anopheles* larvae, the unstructured formation of peri-urban squatter settlements, and the shifting localities of urban agriculture represent countervailing forces that influence the details of program implementation and the corresponding cost accounting.

Finally, the importance of having a UMCP thoroughly integrated with the management structure of the city health system cannot be overemphasized. The sharp separation between JICA and the government responsibilities, as dictated by the original bilateral agreement between the governments of Tanzania and Japan, did not facilitate a sustainable program. However, the current organizational structure of health system management put together by the Dar es Salaam City Council is an excellent vehicle thru which to implement urban malaria control going forward.⁴⁷

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